US009441870B2

(12) **United States Patent**
Nikkanen

(10) **Patent No.: US 9,441,870 B2**
(45) **Date of Patent: Sep. 13, 2016**

(54) **SNOW MAKING APPARATUS**

(71) Applicant: **John Pentti Nikkanen**, West Hartford, CT (US)

(72) Inventor: **John Pentti Nikkanen**, West Hartford, CT (US)

(73) Assignee: **LP Snow Systems, LLC**, West Hartford, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/223,486**

(22) Filed: **Mar. 24, 2014**

(65) **Prior Publication Data**

US 2014/0284396 A1 Sep. 25, 2014

Related U.S. Application Data

(60) Provisional application No. 61/804,454, filed on Mar. 22, 2013.

(51) **Int. Cl.**

F25C 3/04	(2006.01)
B05B 7/06	(2006.01)
B05B 1/34	(2006.01)
B05B 7/10	(2006.01)

(52) **U.S. Cl.**

CPC ***F25C 3/04*** (2013.01); ***B05B 1/3421*** (2013.01); ***B05B 1/3426*** (2013.01); ***B05B 7/06*** (2013.01); ***B05B 7/10*** (2013.01); *F25C 2303/00* (2013.01); *F25C 2303/0481* (2013.01)

(58) **Field of Classification Search**

CPC F25C 3/04; F25C 2303/00; F25C 2303/0481; B05B 1/3426; B05B 1/3421; B05B 7/06; B05B 7/10

USPC 239/14.2, 403–406, 419, 423, 424, 468

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,908,903	A *	9/1975	Burns, Jr.	239/14.2
4,353,504	A *	10/1982	Girardin et al.	239/14.2
5,135,167	A *	8/1992	Ringer	239/14.2
5,909,844	A *	6/1999	Nilsson	239/14.2
6,129,290	A *	10/2000	Nikkanen	239/14.2
7,114,662	B1	10/2006	Nikkanen	

* cited by examiner

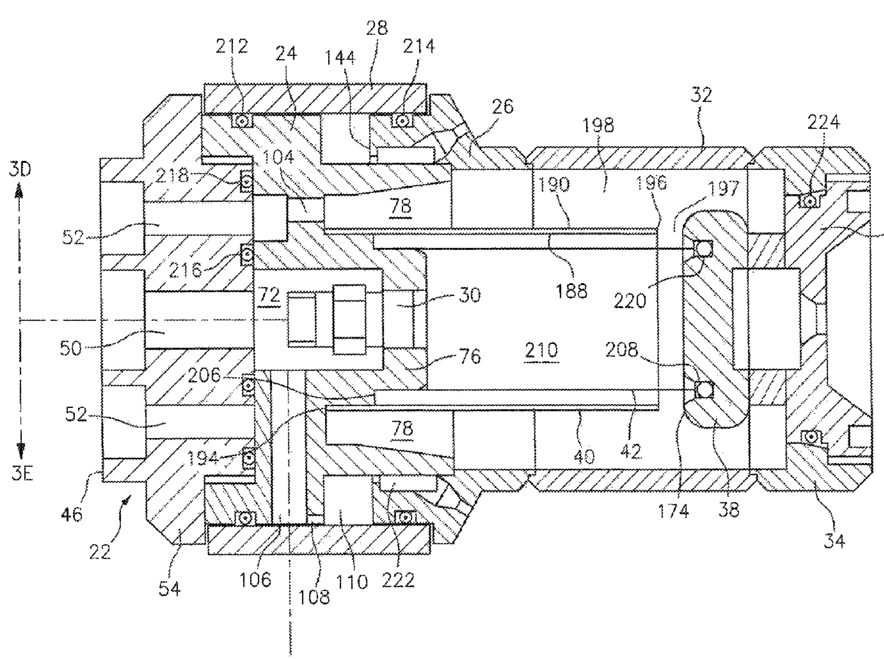
Primary Examiner — Steven J Ganey

(74) *Attorney, Agent, or Firm* — O'Shea Getz P.C.

(57) **ABSTRACT**

A snow making apparatus is provided that includes a manifold, a nucleator annular chamber, and a plurality of nucleator nozzles. The manifold is configured to receive water from a water source and air from an air source. The nucleator annular chamber is configured to receive an air-water mixture from first passages, which first passages are oriented to direct the air-water mixture tangentially into the nucleator annular chamber for subsequent circumferential and axial travel within the annular chamber. The plurality of nucleator nozzles is positioned to receive the air-water mixture from the nucleator annular chamber.

19 Claims, 7 Drawing Sheets



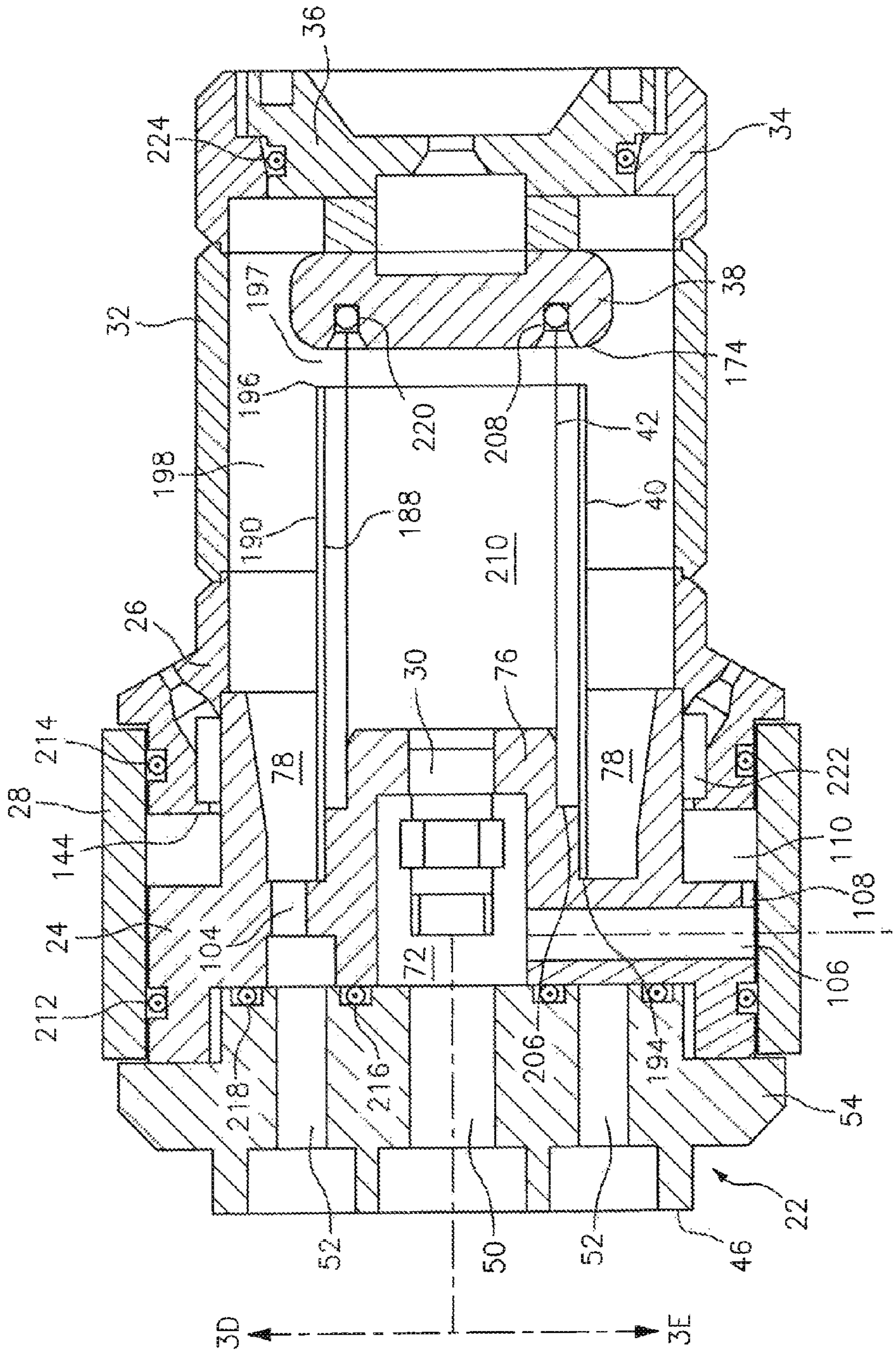

36
224
34
32
197
38
174
196
220
208
42
198
188
40
190
210
26
30
76
214
78
78
222
28
144
110
108
24
104
72
106
212
218
216
206
194
54
52
50
52
46
22
3D
3E

FIG. 1

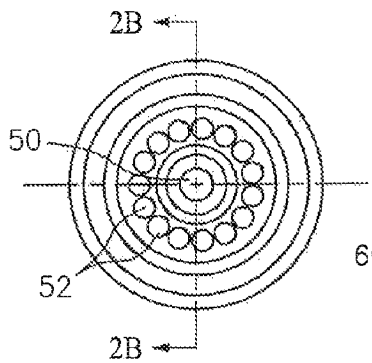


FIG. 2A

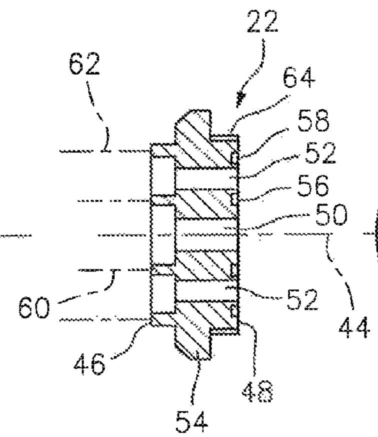


FIG. 2B

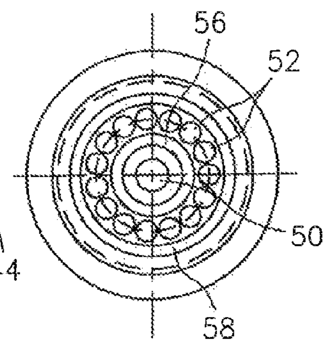


FIG. 2C

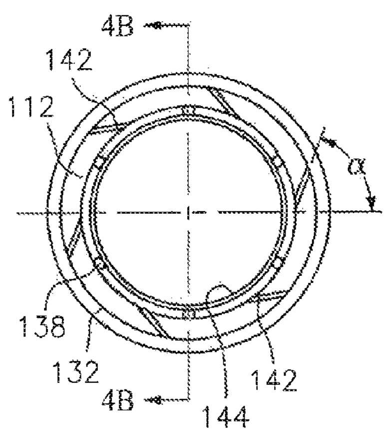


FIG. 4A

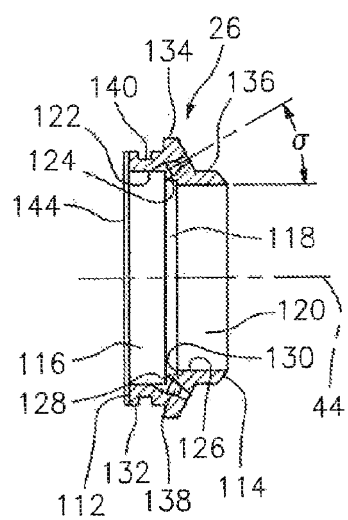


FIG. 4B

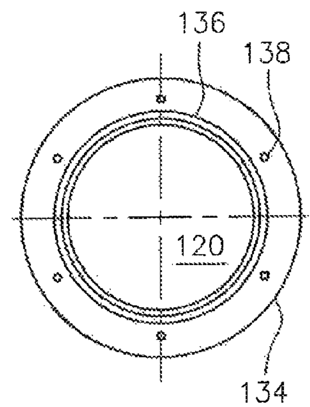


FIG. 4C

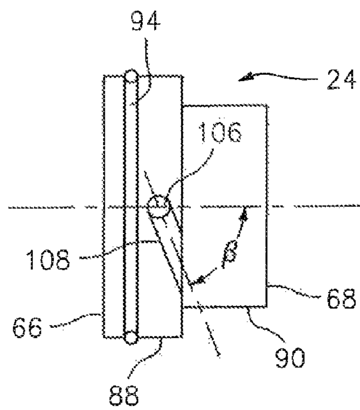


FIG. 3A

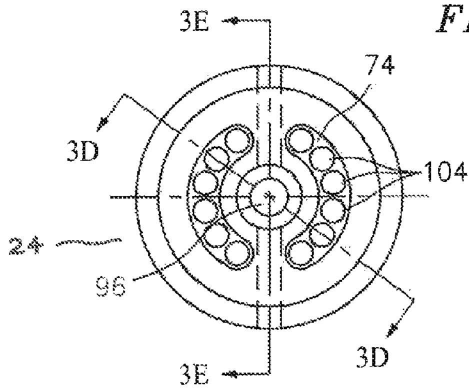


FIG. 3B

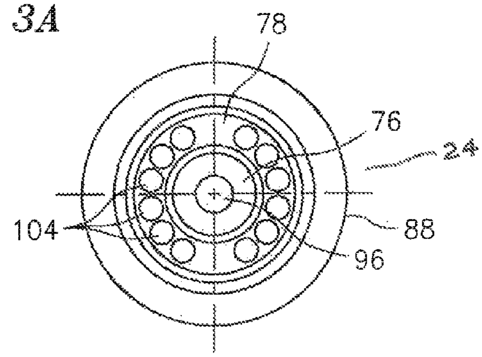


FIG. 3C

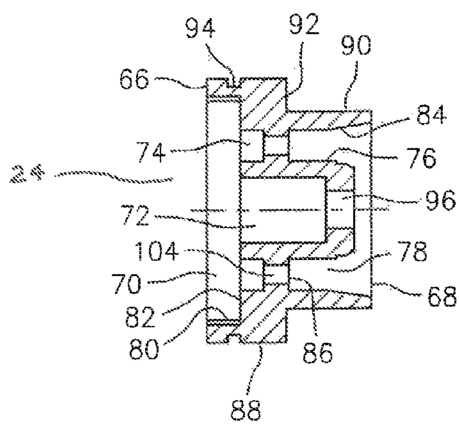


FIG. 3D

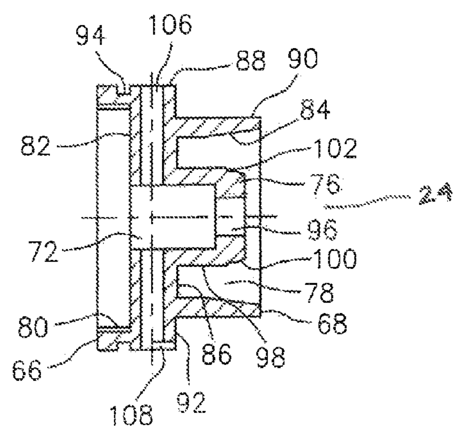


FIG. 3E

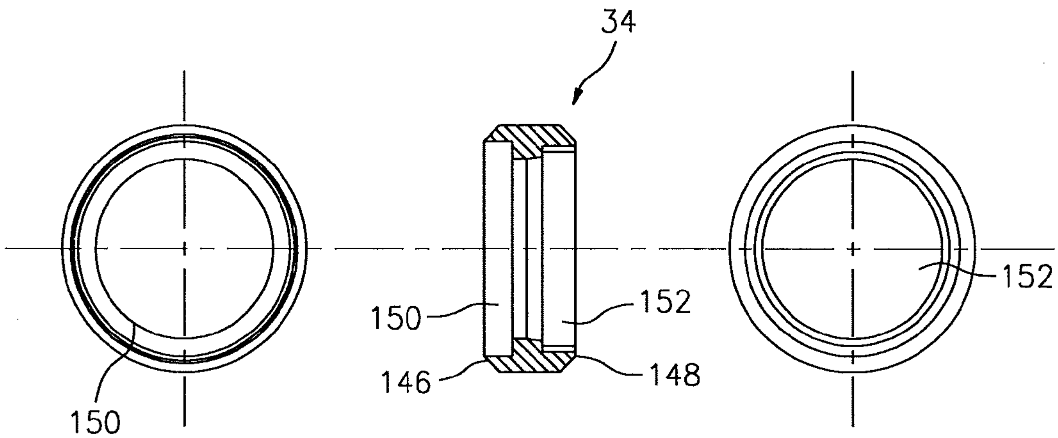


FIG. 5A FIG. 5B FIG. 5C

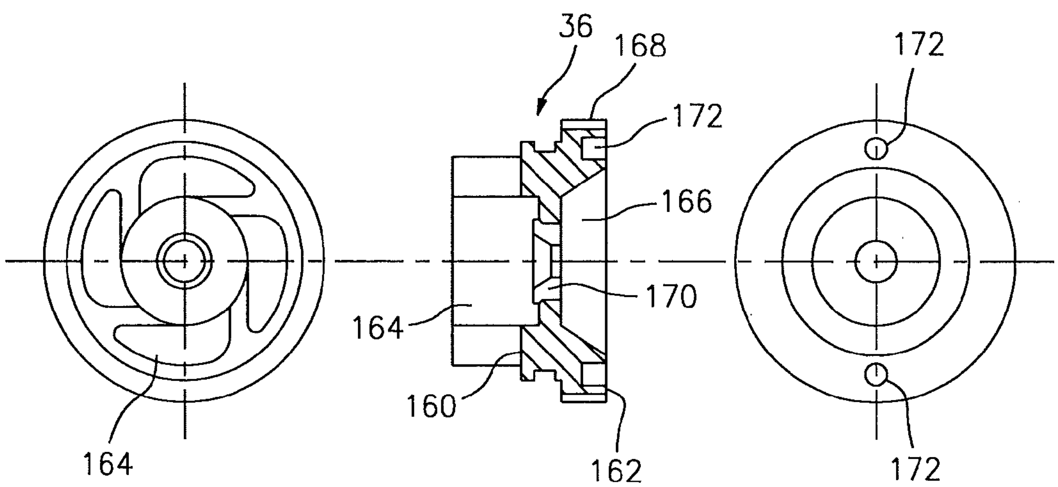


FIG. 6A FIG. 6B FIG. 6C

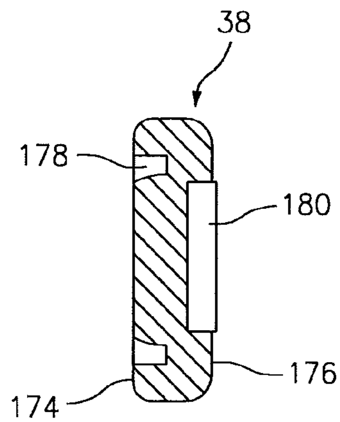


FIG. 7

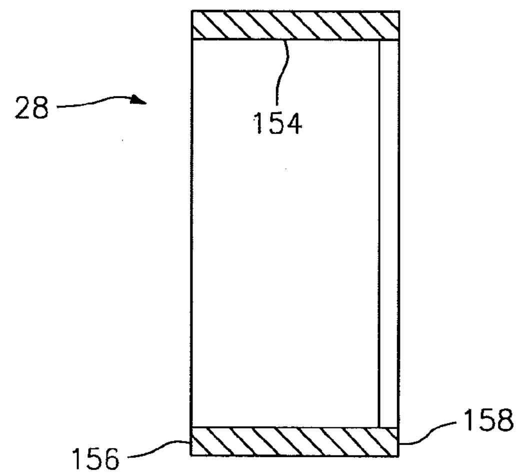


FIG. 8

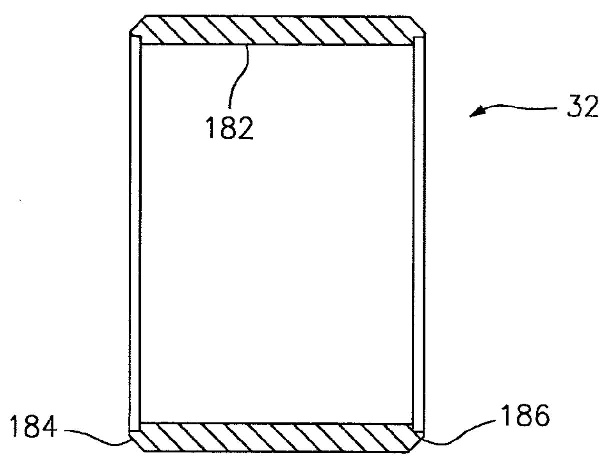


FIG. 9

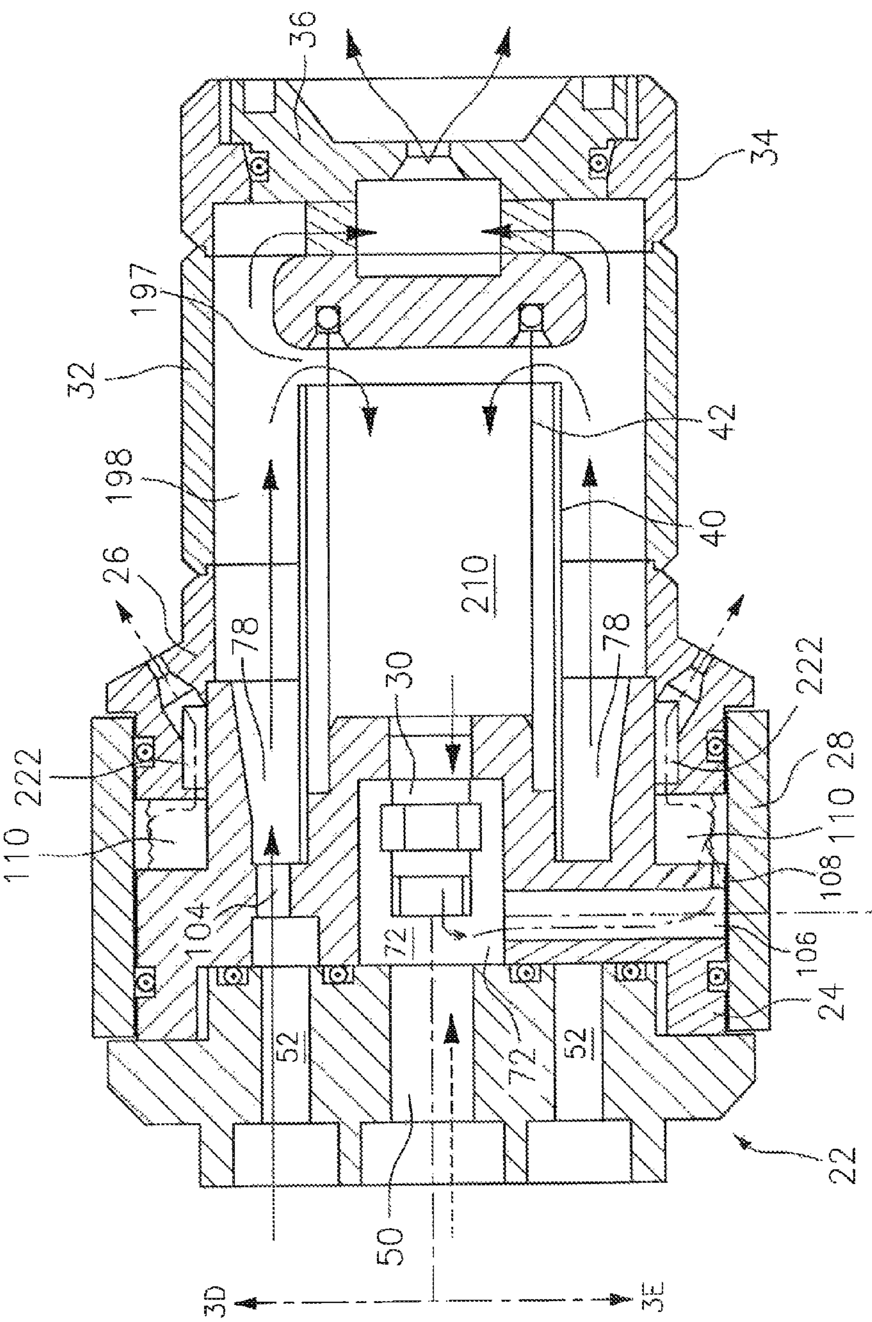

36
34
197
32
42
198
40
26
210
78
78
30
222
222
110
28
110
108
104
72
106
24
52
52
72
72
50
22
3D
3E

FIG. 10

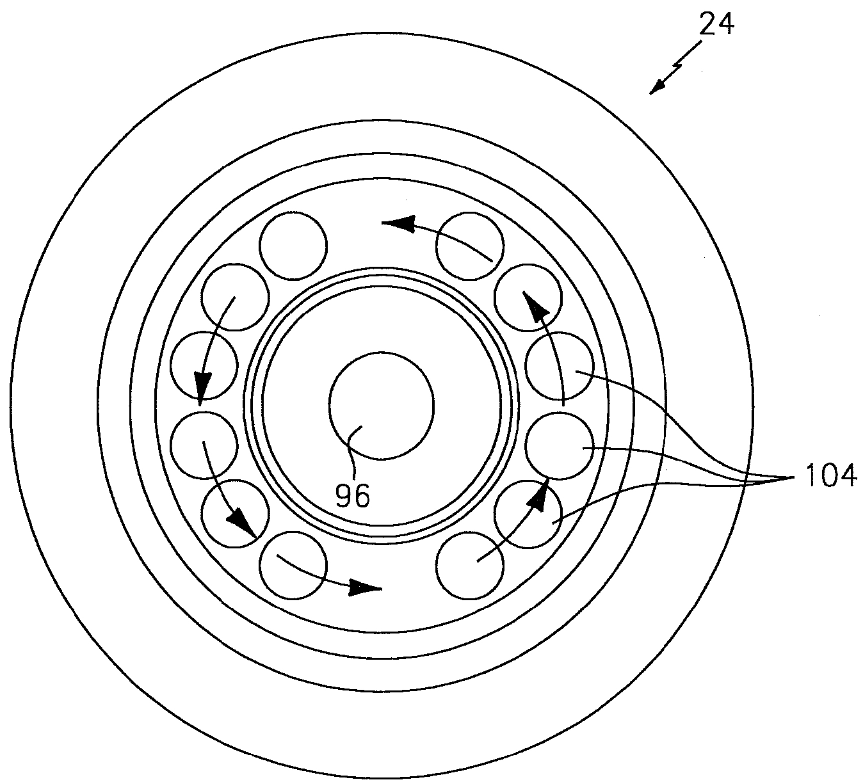


FIG. 11

SNOW MAKING APPARATUS

This application claims priority to U.S. Patent Appln. No. 61/804,454 filed Mar. 22, 2013, which application is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to devices for making artificial snow, in particular, to devices which use water and air to form and project snow over outdoor areas, such as ski slopes.

2. Background Information

For a number of years it has been the practice to employ equipment to deposit artificially made snow on outdoor surfaces, such as ski slopes, when nature does not provide the desired quantity of snow. A variety of mechanical devices have been employed. Generally, the approach is to take water droplets and convert them to frozen particles. Prior art devices typically break up a stream of water by means of pressure atomizing and or two-fluid (air-water) atomizing. Often fans are used to provide an airstream which entrains the droplets as they become frozen, and better to carry them through space and deposit them across a wide area.

There are various problems and limitations connected with prior art snow making devices. They include complexity, noise, reliability, weight, difficult maneuverability, low efficiency in covering a desired area, poor ability for making snow at comparatively warm temperatures, high initial cost, and high operating cost.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, a snow making apparatus is provided that includes a manifold, a nucleator annular chamber, and a plurality of nucleator nozzles. The manifold is configured to receive water from a water source and configured to receive air from an air source. The nucleator annular chamber is configured to receive an air-water mixture from first passages, which first passages are oriented to direct the air-water mixture tangentially into the nucleator annular chamber for subsequent circumferential and axial travel within the annular chamber. The plurality of nucleator nozzles is positioned to receive the air-water mixture from the nucleator annular chamber. The nucleator nozzles are configured to allow the air-water mixture to exit the apparatus through the nozzles.

According to another aspect of the present invention, a snow making apparatus is provided that includes a manifold, a nucleator mix nozzle, a primary nozzle, an annular cavity, and a filter. The manifold is configured to receive water from a water source and configured to receive air from an air source. The annular cavity is disposed downstream of the manifold, configured to receive the water from the manifold. The filter has an aft end. The filter is configured to receive a portion of the water traveling through the annular cavity, which portion is directed to travel through the nucleator mix nozzle. The remaining portion of the water traveling through the annular cavity is directed to exit the apparatus through the primary nozzle.

According to another aspect of the present invention, a snow making apparatus is provided that includes a manifold, a first ring, a second ring, a primary nozzle, a nucleator mix nozzle, and a nucleator annular chamber. The manifold is configured to receive water from a water source and configured to receive air from an air source. The first ring has a plurality of water passages positioned to receive the water from the manifold. The second ring has a plurality of nucleator nozzles. The primary nozzle is attached to a primary nozzle ring. The nucleator annular chamber is configured to receive an air-water mixture from first passages disposed in the second ring, which first passages are oriented to direct the air-water mixture tangentially into the nucleator annular chamber for subsequent circumferential and axial travel within the annular chamber. The nucleator nozzles are positioned to receive the air-water mixture from the nucleator annular chamber. The nucleator nozzles are configured to allow the air-water mixture to exit the apparatus through the nozzles.

In one or more of the aspects of the snow making apparatus described above, the nucleator annular chamber and first passages are configured to cause the air-water mixture circumferentially and axially traveling within the nucleator annular chamber to experience centrifugal forces sufficient to overcome gravitational forces during normal operating conditions.

The foregoing and other objects, features and advantages of the invention will become more apparent from the following description of preferred embodiments and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic sectional view of an embodiment of the present snow making apparatus (i.e., "snowgun").

FIG. **2**A is a diagrammatic planar view of the first end surface of the fluid inlet manifold element of the present snowgun.

FIG. **2**B is a diagrammatic sectional view of the fluid inlet manifold element of the present snowgun.

FIG. **2**C is a diagrammatic planar view of the second end surface of the fluid inlet manifold element of the present snowgun.

FIG. **3**A is a diagrammatic side view of the nucleator swirl ring element of the present snowgun.

FIG. **3**B is a diagrammatic planar view of the first end surface of the nucleator swirl ring element of the present snowgun.

FIG. **3**C is a diagrammatic planar view of the second end surface of the nucleator swirl ring element of the present snowgun.

FIG. **3**D is a diagrammatic sectional view of the nucleator swirl ring element of the present snowgun.

FIG. **3**E is a diagrammatic sectional view of the nucleator swirl ring element of the present snowgun.

FIG. **4**A is a diagrammatic planar view of the first end surface of the nucleator nozzle ring element of the present snowgun.

FIG. **4**B is a diagrammatic sectional view of the nucleator swirl nozzle ring element of the present snowgun.

FIG. **4**C is a diagrammatic planar view of the second end surface of the nucleator nozzle ring element of the present snowgun.

FIG. **5**A is a diagrammatic planar view of the first end surface of the primary nozzle ring element of the present snowgun.

FIG. **5**B is a diagrammatic sectional view of the primary nozzle ring element of the present snowgun.

FIG. **5**C is a diagrammatic planar view of the second end surface of the primary nozzle ring element of the present snowgun.

FIG. **6**A is a diagrammatic planar view of the first end surface of the primary nozzle element of the present snowgun.

FIG. **6**B is a diagrammatic sectional view of the primary nozzle element of the present snowgun.

FIG. **6**C is a diagrammatic planar view of the second end surface of the primary nozzle ring element of the present snowgun.

FIG. **7** is a diagrammatic cross-sectional view of the end cap element of the present snowgun.

FIG. **8** is a diagrammatic cross-sectional view of the swirl sleeve element of the present snowgun.

FIG. **9** is a diagrammatic cross-sectional view of the intermediary ring element of the present snowgun.

FIG. **10** is a diagrammatic sectional view of an embodiment of the present snowgun, illustrating fluid flow paths through the snowgun.

FIG. **11** is an enlarged view of the second end surface view shown in FIG. **3**, illustrating fluid swirl direction associated with angled axial passages.

DETAILED DESCRIPTION

Referring to FIG. **1**, an embodiment of the present snow making apparatus **20** (hereinafter referred to as a "snowgun **20**") includes a fluid inlet manifold **22**, a nucleator swirl ring **24**, a nucleator nozzle ring **26**, a swirl sleeve **28**, a nucleator metering nozzle **30**, an intermediary ring **32**, a primary nozzle ring **34**, a primary nozzle **36**, an end cap **38**, an internal flow sleeve **40**, and a water filter **42**. The aforesaid elements are described herein individually to facilitate the description and understanding of this embodiment of the present apparatus. One or more of the elements may be combined into unitary elements and still be within the scope of the present invention. In addition, the embodiment shown in FIGS. **1-11** is shown in a circular/tubular configuration having a central axis **44**, which configuration is advantageous for manufacturing purposes. The present invention is not limited to this configuration.

Referring to FIGS. **2**A-**2**C, the fluid inlet manifold **22** includes a body extending axially between a first end surface **46** and a second end surface **48**, a centrally located air passage **50**, a plurality of water passages **52**, a radially extending flange **54**, an inner radial seal channel **56**, and an outer radial seal channel **58**. Relatively speaking, the first end surface **46** may be described as being "aft" of the second end surface **48**, and the second end surface **48** may be described as being "forward" of the first end surface **46**. The inner and outer radial seal channels **56**, **58** are disposed in the second end surface **48**. As shown in imaginary lines in FIG. **2**B, an air source conduit **60** (e.g., a pipe, tube, etc.) is typically attached to the manifold **22** between the air passage **50** and the water passages **52** to provide an air conduit to the air passage **50**. Air at an elevated pressure (e.g., relative to ambient produced by a compressor) and a known volumetric flow rate is provided to the snowgun **20** via the air source conduit **60**. Also as shown in imaginary lines, a water source conduit **62** (e.g., a pipe, tube, etc.) is typically attached to the manifold **22** at or outside the water passages **52** to provide a water conduit to the water passages **52**. Water at an elevated pressure (e.g., relative to ambient produced by a pump) and a known volumetric flow rate is provided to the snowgun **20** via the water source conduit **62**. In the embodiment shown in FIGS. **2**A-**2**C, a portion **64** of the exterior surface of the body is threaded to permit attachment of the manifold **22** to the nucleator swirl ring **24**.

Referring to FIGS. **3**A-**3**E, the nucleator swirl ring **24** includes a body extending axially between a first end surface **66** and a second end surface **68**, a manifold cavity **70**, a metering nozzle cavity **72**, a plurality of flow channels **74**, a hub **76**, and a cavity **78**. The manifold cavity **70** is disposed in the first end surface **66** and includes an outer diameter surface **80**, and a radial surface **82**. The metering nozzle cavity **72** is disposed in the radial surface **82** of the manifold cavity **70**. The plurality of arcuate channels **74** is disposed in the radial surface **82** of the manifold cavity **70**, radially outside of the metering nozzle cavity **72**. The embodiment shown in FIGS. **3**A-**3**E shows a pair of flow channels **74**, but the nucleator swirl ring **24** is not limited to the two flow channel configuration. The cavity **78** is disposed in the second end surface **68** and includes an inner diameter surface **84**, and a radial surface **86**. In the embodiment shown in FIGS. **3**A-**3**E, a portion of the inner diameter surface **84** of the cavity **78** is disposed at an non-parallel angle to the central axis **44** of the snowgun **20**; e.g., within the portion of the inner diameter surface **84**, the radius of the inner diameter surface **84** increases in the direction toward the second end surface **68**, thereby decreasing the contiguous wall thickness. The exterior of the nucleator swirl ring **24** includes a first outer diameter surface **88** extending from the first end surface **66**, a second outer diameter surface **90** extending from the second end surface **68**, and a radial surface **92** extending between the first and second outer diameter surfaces **88**, **90**. The diameter of the first outer diameter surface **88** is greater than the diameter of the second outer diameter surface **90**. An O-ring seal channel **94** is disposed in the first outer diameter surface **88**.

The hub **76** is disposed contiguous with the metering nozzle cavity **72**. A first passage **96** extends through the hub **76**, permitting fluid (e.g., water) passage through the nucleator swirl ring **24**. The hub **76** includes a first outer diameter surface **98**, a second outer diameter surface **100**, and a radial surface **102** extending between the first and second outer diameter surfaces **98**, **100**. The diameter of the first outer diameter surface **98** is greater than the diameter of the second outer diameter surface **100**.

A plurality of axial passages **104** extend between the flow channels **74** and the cavity **78**, permitting fluid (e.g., water) flow through the nucleator swirl ring **24**. In the embodiment shown in FIGS. **3**A-**3**E (FIG. **3**D is a cross-sectional view along the slice line "**3**D-**3**D" shown in FIG. **3**B), the axial passages **104** extend exclusively in an axial direction, parallel to the central axis **44**. In a preferred embodiment, the axial passages **104** are disposed at a tangential angle (e.g., in the range of 15-20 degrees) relative to the central axis **44** to direct water exiting the axial passages **104** to travel both circumferentially and axially (i.e., a direction that causes the water to circumferentially "swirl") as will be explained below (e.g., see FIG. **11**).

Referring to FIG. **1**, the nucleator metering nozzle **30** is disposed in the metering nozzle cavity **72**, attached to the hub **76**; e.g., by screw thread. The nucleator metering nozzle **30** includes an orifice having a diameter, through which water may flow.

Referring to FIGS. **3**A-**3**E (FIG. **3**E is a cross-sectional view along the slice line "**3**E-**3**E" shown in FIG. **3**B), the nucleator swirl ring **24** also includes a plurality of radial passages **106**, each extending radially between the metering nozzle cavity **72** and an angled passage **108** (see FIG. **3**A). Each angled passage **108** extends in a direction having a circumferential component and an axial component (e.g., shown as angle "β" relative to the central axis **44**), between the radial passage **106** and the first outer diameter surface

88, breaking through to the radial surface **92** extending between the first and second outer diameter surfaces **88**, **98** of the swirl ring **24**. As will be described below, the orientation of the angled passages **108** is such that water flowing through the angled passages **108** tangentially enters a swirl chamber **110** (formed by the nucleator swirl ring **24**, the nucleator nozzle ring **26**, and the swirl sleeve **28**—see FIGS. **1** and **10**) for travel around the outer circumference of the swirl chamber **110**.

It should be noted that FIGS. **1** and **10** show a cross-section of the nucleator swirl ring **24** along a first sectional line (labeled as "**3**D") that passes through an axial passage **104**, and along a second sectional line (labeled as "**3**E") that gasses through a radial passage **106** to facilitate the description of then present snowgun **20**.

Referring to FIGS. **4**A-**4**C, the nucleator nozzle ring **26** includes a body extending axially between a first end surface **112** and a second end surface **114**, a first cavity **116**, a second cavity **118**, and a bore **120**. The first cavity **116** is defined in part by a first inner diameter surface **122**. The second cavity **118** is defined in part by a second inner diameter surface **124**. The bore **120** is defined in part by a third inner diameter surface **126**. A first radial surface **128** extends between the first inner diameter surface **122** and the second inner diameter surface **124**. A second radial surface **130** extends between the second inner diameter surface **124** and the third inner diameter surface **126**.

The nucleator nozzle ring **26** further includes a first outer diameter surface **132**, a radially extending flange **134**, a second outer diameter surface **136**, and a plurality of nucleator nozzles **138**. A channel **140** for receiving an O-ring is disposed in the first outer diameter surface **132**. In the embodiment shown in FIGS. **4**A-**4**C, the second end surface **114** includes a portion of a lap joint, which lap joint permits a mating fit with the intermediary ring **32** when the snowgun **20** is assembled. The nucleator nozzles **138** are disposed, spaced apart from one another, around the circumference of the nucleator nozzle ring **26**. Each nucleator nozzle **138** includes a centerline disposed at an angle "σ" (e.g., where σ is in the range of 30-45 degrees) relative to the central axis **44**. The embodiment shown in FIGS. **4**A-**4**C shows six (6) nucleator nozzles **138** extending through the flange **134**, uniformly spaced around the circumference of the flange. The nozzle ring **26** is not limited to having six nozzles **138**.

The nucleator nozzle ring **26** further includes a plurality of swirl passages **142** disposed in the first end surface **112**, spaced apart from one another around the circumference of the first end surface **112**. Each swirl passage **142** has length that extends along an axis that is disposed at an angle "α" relative to a radial centerline of the nozzle ring. As will be explained below, the angle "α" is such that water passing through the passages **142** in the direction from the first outer diameter surface **132** toward the first cavity **116** enters the first cavity tangentially. As a result, the water is directed to travel (i.e., "swirl") around the circumference of the first cavity **116**.

In a preferred embodiment, the nucleator nozzle ring **26** includes a rib **144** disposed at the first end surface edge of the first cavity **116**, which rib **144** extends a distance radially inwardly.

Referring to FIGS. **5**A-**5**C, the primary nozzle ring **34** includes a body extending axially between a first end surface **146** and a second end surface **148**, a first cavity **150**, and a second cavity **152**, and a bore extending there between. The first cavity **150** is disposed in the first end surface **146**. The second cavity **152** is disposed in the second end surface **148**, and includes a threaded inner diameter for thread engagement with the primary nozzle **36**. In the embodiment shown in FIGS. **5**A-**5**C, the first end surface **146** includes a portion of a lap joint, which lap joint permits a mating fit with the intermediary ring **32** when the snowgun **20** is assembled.

Referring to FIG. **8**, the swirl sleeve **28** includes a tubular body having an inner diameter surface **154**, and which body extends axially between a first end surface **156** and a second end surface **158**.

Referring to FIGS. **6**A-**6**C, the primary nozzle **36** includes a includes a body extending axially between a first end surface **160** and a second end surface **162**, a plurality of flow elements **164**, a first cavity **166**, a bore, an outer diameter surface **168**, and a nozzle insert **170** fixedly attached within the bore. The first cavity **166** is disposed in the second end surface **162**, and includes an angled inner diameter wall that increases in radius in the direction toward the second end surface **162**. The outer diameter surface **168** is threaded for thread engagement with the threaded inner diameter of the nozzle ring second cavity **118**. The embodiment shown in FIGS. **6**A-**6**C shows a pair of circular cavities **172** disposed in the second end surface **162**, which cavities are configured for engagement with a tool for moving the primary nozzle **36** relative to the primary nozzle ring **34**; e.g., screwing the nozzle **36** into or out of the nozzle ring **26**. The flow elements **164** extend axially outwardly from the first end surface **160**, spaced apart from one another, each having a distal end. The inter-flow element spacing creates tangential flow passages through which water may enter the nozzle **36** and subsequently exit the snowgun **20**. The water exiting the primary nozzle **36** forms a conical-shaped as it extends away from the snowgun **20**.

Referring to FIG. **7**, the end cap **38** includes a body extending axially between a first end surface **174** and a second end surface **176**. An annular channel **178** is disposed in the first end surface **174**, which channel is configured to receive an O-ring. A cavity **180** is disposed in the second end surface **176**. The cavity **180** is sized to receive the distal ends of the flow elements **164**. Collectively, the end cap **38** and flow elements **164** create a flow swirl chamber which produces a particular orientation for the flow exiting the nozzle **36**.

Now referring to FIG. **9**, the intermediary ring **32** includes a tubular body having an inner diameter surface **182**, and which body extends axially between a first end surface **184** and a second end surface **186**. In the embodiment shown in FIG. **9**, the first end surface includes a portion of a lap joint, which lap joint permits a mating fit with the nucleator nozzle ring **26** when the snowgun **20** is assembled. The second end surface **186** also includes a portion of a lap joint, which lap joint permits a mating fit with the primary nozzle ring **34** when the snowgun **20** is assembled.

Now referring to FIG. **1**, the internal flow sleeve **40** includes a tubular body having an inner diameter surface **188**, and outer diameter **190**, and a length extending axially between a first end surface **194** and a second end surface **196**. The outer diameter **190** of the internal flow sleeve **40** is less than the inner diameter of the intermediary ring **32**. When the snowgun **20** is assembled, the difference in the two diameters creates an axially extending annular cavity **198** through which water may flow. The inner diameter of the internal flow sleeve **40** is sized to receive at least a portion of the first outer diameter surface **98** of the hub **76** portion of the nucleator swirl ring **24**; e.g., a slight interference fit to keep the internal flow sleeve **40** attached to the nucleator swirl ring **24**. The length of the internal flow sleeve **40** is such that when the snowgun **20** is assembled, the second end surface **196** is spaced apart from the first end surface **174** of the end cap **38**, thereby creating a flow passage **197** there between.

Now referring to FIG. **1**, the water filter **42** includes a tubular body having an inner diameter **200**, a length extending axially between a first end **206** and a second end **208**, and an internal cavity **210**. The inner diameter **200** of the water filter **42** is sized to receive at least a portion of the second outer diameter surface **100** of the hub **76** portion of the nucleator swirl ring **24**; e.g., a slight interference fit to keep the water filter **42** attached to the nucleator swirl ring **24**. The length of the water filter **42** is such that when the snowgun **20** is assembled, the first end **206** is engaged with the hub **76** and the second end **208** is engaged with an O-ring disposed in the first end surface **174** of the end cap **38**. As a result, water passing through the flow passage **197** formed between the second end surface **196** of the internal flow sleeve **40** and the end cap **38** must pass through the water filter **42** prior to encountering the nucleator metering nozzle **30** as will be explained below. An example of an acceptable water filter **42** is a screen having apertures, each with a diameter that is less than the orifice diameter of the nucleator metering nozzle **30** (e.g., to prevent passage particles or debris of a size that could clog the nucleator metering nozzle orifice). The present invention is not limited to using a screen type water filter **42**.

The present snowgun **20** may be assembled in a number of different ways, and is not limited to any particular manner As indicated above, one or more of the elements of the present snowgun **20** may be combined into unitary elements and still be within the scope of the present invention. To illustrate how the snowgun may be assembled in a non-limiting example, the following description is offered.

As can be seen from the FIGURES, when the snowgun **20** is assembled, a portion of the second outer diameter surface **90** of the nucleator swirl ring **24** is received within the first and second cavities **116**, **118** of the nucleator nozzle ring **26**. The nucleator swirl ring **24** and the nucleator nozzle ring **26** may be joined together by weld, for example.

As described above, the intermediary ring **32**, the nucleator nozzle ring **26**, and the primary nozzle ring **34** may have mating lap joints. At each lap joint the respective pieces may be welded together. It can be seen, therefore, that the nucleator swirl ring **24**, the nucleator nozzle ring **26**, the intermediary ring **32**, and the primary nozzle ring **34** may be joined together as a unitary piece.

The nucleator metering nozzle **30** may be attached to the hub **76** of the nucleator swirl ring **24** by, for example, screw thread.

The swirl sleeve **28** may be slid over the first outer diameter surfaces **88**, **132** of the nucleator swirl ring **24** and the nucleator nozzle ring **26**, respectively. The fluid inlet manifold **22** may then be screwed into the nucleator swirl ring **24**. The flanges **54**, **134** of fluid inlet manifold **22** and the nucleator nozzle ring **26** hold the swirl sleeve **28** in place. As can be seen in FIG. **1**, when assembled, a first O-ring **212** seals the interface between the swirl sleeve **28** and the nucleator swirl ring **24**, and a second O-ring **214** seals the interface between the swirl sleeve **28** and the nucleator nozzle ring **26**. In addition, the annular swirl chamber **110** formed by the nucleator swirl ring **24**, the nucleator nozzle ring **26**, and the swirl sleeve **28** can be seen from FIG. **1**. A third O-ring **216** and a fourth O-ring **218** provides seals between the manifold **22** and nucleator swirl ring **24**.

The internal flow sleeve **40** may be inserted through the primary nozzle ring **34** and into the intermediary ring **32** a distance sufficient to allow the first and second outer diameter surfaces **88**, **90** of the hub **76** to be received within the internal flow sleeve **40**. The second end surface **186** of the internal flow sleeve **40** is slid into contact with the base of the cavity **78** of the nucleator swirl ring **24**. As indicated above, the inner diameter **188** of the internal flow sleeve **40** may be sized to form a slight interference fit with the first outer diameter surface **98** of the hub **76** to keep the internal flow sleeve **40** attached to the nucleator swirl ring **24**.

The water filter **42** may be inserted through the primary nozzle ring **34** and into the intermediary ring **32** a distance sufficient to allow the second outer diameter surface **100** of the hub **76** to be received within the water filter **42**. The second end **208** of the water filter **42** is slid into contact with the first radial surface **102** of the hub **76**. The inner diameter **200** of the water filter **42** may be sized to form a tight slid fit or a slight interference fit with the second outer diameter surface **100** of the hub **76** to keep the water filter **42** attached to the nucleator swirl ring **24**.

The end cap **38** may be attached to the flow elements of the primary nozzle **36**; e.g., by weld.

The primary nozzle **36** (with the end cap **38** attached) may then be inserted into the primary nozzle ring **34**. As the nozzle/end cap assembly is slid into the primary nozzle ring **34**, the end cap **38** will extend into the intermediary ring **32**, and the second end of the water filter **42** will engage an **0**-ring **220** disposed in the first end surface channel **178** of the end cap **38**. The primary nozzle/end cap assembly can be secured to the primary nozzle ring **34** by screwing the nozzle **36** and the nozzle ring **34** together. An O-ring **224** seals between the primary nozzle **36** and the primary nozzle ring **34**.

Referring to FIGS. **1** and **10**, in the operation of the snowgun **20**, water (depicted as a solid line) at an elevated pressure (e.g., in the range of 250-650 psig) and at a flow rate (e.g., in the range of 10-25 gpm) is directed through the fluid inlet manifold **22**, through the arcuate channels **74** and through the plurality of axial passages **104** (e.g., see FIGS. 3A-3D) disposed in the nucleator swirl ring **24**. The water exits the axial passages **104** and enters the cavity **78** on the opposite side of the nucleator swirl ring **24**.

As indicated above, in a preferred embodiment, the axial passages **104** are disposed at a tangential angle (e.g., in the range of 15-20 degrees) relative to the central axis **44** to direct water exiting the axial passages **104** to travel both circumferentially and axially; i.e., a direction that causes the water to circumferentially "swirl" (e.g., diagrammatically shown in FIG. **11** within cavity **78** and beyond in the annular cavity **198**). The water swirl within the cavity **78**, and the decreasing wall thickness (between the cavity **78** and the second outer diameter surface **90** of the nucleator swirl ring **24**), provide advantageous heat transfer in the region. The swirling action enables the water to travel at a faster velocity that would be otherwise possible with only axial travel, and the increased velocity of the water along the inner diameter surface **84** of the cavity **78** assists in the desirable heat transfer. To fully appreciate the significance of the heat transfer, consider that prior to operation the snowgun **20** may initially be at a very low ambient temperature (e.g., low as zero degrees Fahrenheit—0° F.), particularly at start-up when the snowgun **20** is stored outside. After the snowgun is "turned on" and despite an initial water temperature of between 34 and 38 degrees Fahrenheit (34-38° F.), it is possible that one or more of the nucleator nozzles **138** may initially clog with frozen water. The present snowgun **20** addresses this issue, for example, by the water swirl within the cavity **78**, and the decreasing wall thickness (between the cavity **78** and the second outer diameter surface **90** of the nucleator swirl ring **24**). Heat transfer from the water increases the temperature of the snowgun **20** and thaws any nucleator nozzle **138** that may be clogged with frozen water in a very short period of time. This is particularly advantageous because in the absence of fluid flow through the nucleator nozzles **138** (and the production of frozen particles—sometimes referred to as "nuclei" via the nozzles) the ability of the snowgun **20** to produce snow is negatively affected.

The water exits the cavity **78** and enters the annular flow passage **198** formed between the internal flow sleeve **40** and the intermediary ring **32**. A portion of the water then travels through the passage **197** formed between the second end surface **196** of the internal flow sleeve **40** and the first end surface **174** of the end cap **38**, through the water filter **42**, and into the internal cavity **210** of the water filter **42**. Once in the internal cavity **210**, the water travels toward and through the nucleator metering nozzle **30**. As indicated above, the apertures in the water filter **42** are smaller in diameter than the nucleator metering nozzle orifice to decrease the possibility of the nucleator metering nozzle orifice getting clogged. Water used for snow making purposes is often drawn from a natural source (e.g., a stream or pond) and consequently often contains debris from the source or debris (e.g., rust) from the piping supplying the water to the snowgun. Hence, the filter **42** increases the operational reliability of the snowgun **20**. In addition, the internal flow sleeve **40** creates a desirable fluid flow path internally within the snowgun **20**. Specifically, the internal flow sleeve **40** forces the water flow within the annular flow passage **198** to travel substantially all of the passage **198**. As a result, the water travels within the passage **198** provides desirable heat transfer relative to the intermediary ring **32**. In addition, in the absence of the internal flow sleeve **40**, a pressure gradient within the annular flow passage **198** can cause undesirable recirculating flow patterns; e.g., water flow entering the filter **42** proximate the end cap **38** may travel within the internal cavity **210** of the filter **42** and exit the cavity **210** and enter back into the annular flow passage **198** proximate the nucleator swirl ring hub **76**.

The remainder of the water flow through the annular flow passage **198** (i.e., the portion of the water that does not enter the water filter **42**) travels past the end cap **38** and enters the primary nozzle **36** via the tangential flow passages between the flow elements **164**. From there the water exits the primary nozzle **36** in a defined conical geometry and into the atmosphere.

At the same time the water is passing through the snowgun, air (depicted as a dotted line) at an elevated pressure (e.g., in the range of 40-100 psig) and flow rate (e.g., in the range of 20-40 scfm) is directed into the centrally located air passage **50** within the fluid inlet manifold **22**, through the manifold **22** and into the metering nozzle cavity **72**. At this point the air mixes with the water passing through the nucleator metering nozzle **30** (air-water mixture is depicted as a dash dot dash line) and is directed out of the metering nozzle cavity **72** via the radial passages **106** extending between the metering nozzle cavity **72** and the respective angled passage **108** (e.g., see FIG. **3**A), and into the swirl chamber **110** formed by the nucleator swirl ring **24**, the nucleator nozzle ring **26**, and the swirl sleeve **28** (e.g., see FIG. **10**). The air-water mixture exiting the angled passages **108** and tangentially entering the swirl chamber **110** travels at very high rate of speed circumferentially within the swirl chamber **110**. Centrifugal forces maintain the mixture along the outer radial portion of the swirl chamber **110**; e.g., against the inner diameter surface **154** of the swirl sleeve **28**. Here again, the present snowgun **20** design provides advantageous heat transfer from fluids (e.g., the air-water mixture) to the snowgun **20**.

An example of flows within the swirl chamber **110** could be 30 cubic feet per minute (cfm) air with 0.5 gallons per minute (gpm) water; i.e., an air/water ("A/W") ratio of sixty (60). In this example, the air in the swirl chamber **110** may be swirling at a velocity of about 100 feet per second, and water film on the radially outer surface at about 20 feet per second. The gravitational forces (i.e., "G" forces) may be on the order of 125 G's, assuring a uniform layer of water disposed on the outer periphery.

To illustrate the significance of the present snowgun **20** design, consider the operation of a prior art snowgun. Most snowguns are attached to long stands that position the snowgun many feet above the surface to be covered with snow—the higher the snowgun, the greater potential reach of the snowgun and the greater the distance the snowgun produced mixture must travel before reaching the ground. The quality of the snow made by the snowgun typically increases with the amount of time the mixture is airborne. In many prior art snowguns, it is not uncommon for ice to build up on the snowgun during operation. If enough ice builds up, the snowgun can freeze and stop producing snow. Once the snowgun stops flowing, any water within the piping leading to the snowgun becomes static and susceptible to freezing and potentially rupturing the piping. The present snowgun **20** design addresses this issue, for example, by heat transfer to the snowgun **20** from the air-water mixture swirling with swirl chamber **110**, thereby inhibiting ice formation on the exterior of the snowgun **20**.

The air-water mixture traveling circumferentially within the swirl chamber **110** also travels axially, and encounters the plurality of swirl passages **142** disposed in the first end surface **112** of the nucleator nozzle ring **26**. The orientation of the swirl passages **142** (e.g., the swirl passage length extending along an axis that is disposed at an angle "a" relative to a radial centerline of the nozzle ring) enables the air-water mixture circumferentially traveling within the swirl chamber **110** to readily exit the swirl chamber **110** in a tangential manner. The air-water mixture travels through the swirl passages **142** (in a direction that is in part radially inward) and enters a nucleator annular chamber **222** formed between the second outer diameter surface **90** of the nucleator swirl ring **24** and the first inner diameter surface **124** of the first cavity **116** of the nucleator nozzle ring **26**. Once the air-water mixture is within the nucleator annular chamber **222**, the mixture travels circumferentially and axially, and subsequently passes out through the nucleator nozzles **138**. In the preferred embodiment that includes a rib **144** disposed at the first end surface edge of the first cavity **116**, the rib **144** helps to maintain the air-water mixture within the nucleator annular chamber **222**. The "swirling" (i.e., circumferential travel at a high velocity) of the air-water mix within the nucleator annular chamber **222** provides several advantages. First the swirling provides a uniform distribution of air-water mixture to the nucleator nozzles **138**. Second, the centrifugal forces acting on the swirling the air-water mixture are also strong enough to overcome gravitational forces acting on the air-water mixture. In operation, snowguns may be positioned in a variety of different orientations. Most of these orientations are such that gravitational forces will, in the absence of the swirl, cause water to collect in the vertically lower portion of the nucleator (the gravitational vector being vertical), thereby negatively influencing the uniformity of the air-water mixture being dispersed through the nucleator nozzles around the circumference of the gun. The swirling flow within the present snowgun **20** solves this problem.

The air-water mixture exiting the nucleator nozzles **138** forms a conical shaped body of air-water mixture. The geometry of the conical shaped body is a function in part of the angle "σ" at which the nucleator nozzles **138** are disposed in the nucleator nozzle ring **26**. As indicated above, the water exiting the snow gun **20** from the primary nozzle also font's a conical shaped body extending away from the snowgun **20**. At some distance from the snowgun **20**, the air-water mixture exiting the nucleator nozzles **138** and the water exiting the primary nozzle mix. Nuclei formed within the air-water mixture interact with the water from the primary nozzle **36** to create snow under the right atmospheric conditions.

The present snowgun can provide an overall air to water (A/W) ratio (cfm/gpm) of about 2.0 at marginal (26-27 degrees F.) wet bulb temperatures . . . see evaporative cooling, and a minimum level of about 0.9 when colder temperatures allow.

Although this invention has been shown and described with respect to the detailed embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and the scope of the invention.

What is claimed is:

1. A snow making apparatus, comprising:

a manifold configured to receive water from a water source and configured to receive air from an air source;

a nucleator annular chamber configured to receive an air-water mixture from first passages, which first passages are oriented to direct the air-water mixture tangentially into the nucleator annular chamber for subsequent circumferential and axial travel within the annular chamber; and

a plurality of nucleator nozzles, which nozzles are positioned to receive the air-water mixture from the nucleator annular chamber, and which nozzles are configured to allow the air-water mixture to exit the apparatus through the nozzles.

2. The snow making apparatus of claim **1**, wherein the nucleator annular chamber and first passages are configured to cause the air-water mixture circumferentially and axially traveling within the nucleator annular chamber to experience centrifugal forces sufficient to overcome gravitational forces during normal operating conditions.

3. The snow making apparatus of claim **2**, wherein the nucleator annular chamber and first passages are configured such that the centrifugal forces direct the air-water mixture toward an outer radial surface of the nucleator annular chamber during normal operating conditions.

4. The snow making apparatus of claim **1**, wherein the apparatus is configured such that the water received from the water source includes a portion that is directed to travel through a nucleator mix nozzle, and the remainder of the water received from the water source is directed to exit the apparatus through a primary nozzle.

5. The snow making apparatus of claim **1**, further comprising a filter having an aft end, which filter is positioned such that the nucleator mix nozzle portion of the water passes through the filter prior to passing through the nucleator mix nozzle.

6. The snow making apparatus of claim **5**, wherein the water filter is a screen.

7. The snow making apparatus of claim **5**, wherein the snow making apparatus further comprises an internal flow sleeve positioned concentrically outside the filter, wherein an annular cavity is formed within the apparatus in part by the internal flow sleeve, and the sleeve is configured to form a flow passage located adjacent the aft end of the water filter, wherein the nucleator mix nozzle portion of the water passes through the flow passage prior to entering the water filter.

8. The snow making apparatus of claim **7**, further comprising a ring having a plurality of water passages positioned to receive the water from the manifold, which passages are disposed at a tangential angle relative to a central axis of the apparatus, which angle directs water exiting the water passages to travel both circumferentially and axially and experience centrifugal forces during normal operating conditions.

9. The snow making apparatus of claim **8**, wherein the water passages are configured such that the centrifugal forces direct the water mixture toward an outer radial surface of a cavity within the ring during normal operating conditions.

10. A snow making apparatus, comprising:

a manifold configured to receive water from a water source and configured to receive air from an air source;

a nucleator mix nozzle;

a primary nozzle;

an annular cavity disposed downstream of the manifold, configured to receive the water from the manifold; and

a filter having an aft end, which filter is configured to receive a portion of the water traveling through the annular cavity, which portion is directed to travel through the nucleator mix nozzle, and the remaining portion of the water traveling through the annular cavity is directed to exit the apparatus through the primary nozzle;

wherein the snow making apparatus further comprises an internal flow sleeve positioned concentrically outside the filter, wherein the annular cavity is formed within the apparatus in part by the internal flow sleeve, and the sleeve is configured to formed a flow passage located adjacent the aft end of the water filter, wherein the nucleator mix nozzle portion of the water passes through the flow passage prior to entering the water filter.

11. The snow making apparatus of claim **10**, further comprising a ring having a plurality of water passages positioned to receive the water from the manifold, which passages are disposed at a tangential angle relative to a central axis of the apparatus, which angle directs water exiting the water passages to travel both circumferentially and axially and experience centrifugal forces during normal operating conditions.

12. The snow making apparatus of claim **11**, wherein the water passages are configured such that the centrifugal forces direct the water mixture toward an outer radial surface of a cavity within the ring during normal operating conditions.

13. A snow making apparatus, comprising:

a manifold configured to receive water from a water source and configured to receive air from an air source;

a first ring having a plurality of water passages positioned to receive the water from the manifold;

a second ring having a plurality of nucleator nozzles;

a primary nozzle attached to a primary nozzle ring;

a nucleator mix nozzle; and

a nucleator annular chamber configured to receive an air-water mixture from first passages disposed in the second ring, which first passages are oriented to direct the air-water mixture tangentially into the nucleator annular chamber for subsequent circumferential and axial travel within the annular chamber;

wherein the nucleator nozzles are positioned to receive the air-water mixture from the nucleator annular chamber, and which nozzles are configured to allow the air-water mixture to exit the apparatus through the nozzles.

14. The snow making apparatus of claim **13**, wherein the nucleator annular chamber and first passages are configured to cause the air-water mixture circumferentially and axially traveling within the nucleator annular chamber to experience centrifugal forces sufficient to overcome gravitational forces during normal operating conditions, which centrifugal forces direct the air-water mixture toward an outer radial surface of the nucleator annular chamber during normal operating conditions.

15. The snow making apparatus of claim **14**, wherein the apparatus is configured such that the water passing through the first ring enters an annular cavity, and includes a portion that is directed to travel through the nucleator mix nozzle, and the remainder of the water is directed to exit the apparatus through the primary nozzle.

16. The snow making apparatus of claim **15**, further comprising a filter having an aft end, which filter is positioned such that the nucleator mix nozzle portion of the water passes through the filter prior to passing through the nucleator mix nozzle.

17. The snow making apparatus of claim **16**, wherein the snow making apparatus further comprises an internal flow sleeve positioned concentrically outside the filter, wherein the annular cavity is formed within the apparatus in part by the internal flow sleeve, and the sleeve is configured to form a flow passage located adjacent the aft end of the water filter, wherein the nucleator mix nozzle portion of the water passes through the flow passage prior to entering the water filter.

18. The snow making apparatus of claim **13**, wherein the water passages disposed in the first ring are positioned to receive the water from the manifold, which passages are disposed at a tangential angle relative to a central axis of the apparatus, which angle directs water exiting the water passages to travel both circumferentially and axially and experience centrifugal forces during normal operating conditions.

19. The snow making apparatus of claim **18**, wherein the water passages are configured such that the centrifugal forces direct the water mixture toward an outer radial surface of a cavity within the first ring during normal operating conditions.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,441,870 B2
APPLICATION NO. : 14/223486
DATED : September 13, 2016
INVENTOR(S) : John Pentti Nikkanen

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the specification,

In Column 11, line 10, please delete “font’s” and insert -- forms --

In the claims,

In Column 12, line 38, please delete “formed” and insert -- form --

Signed and Sealed this
Eighteenth Day of October, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office